UCRL-JC-123737 Abs

Layered Media for Modal and Polarization Control in Optical Waveguides

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Advanced fiber-optic systems for communications and sensing employ increasingly sophisticated combinations of optical and optoelectronic devices to generate, detect, switch and multiplex optical signals. Optical waveguides fabricated on planar substrates provide a practical technology for fabricating and/or integrating such devices.[1,2] Major issues which complicate the deployment of this technology in conventional, single-mode fiber systems are the small mode size and excessive waveguide birefringence. Small mode size increases the difficulty of robust, efficient optical coupling between device and fiber.[2,3] Birefringence can cause a polarization-dependent performance which results in undesirable, time-dependent fading when devices are used with conventional (non-polarization-preserving) fiber.[3] Recently, several techniques utilizing layered media have been proposed to address these issues. This contribution reviews the application of these techniques to optical waveguides in III-V compound semiconductors.

Layered media in the form of multiple quantum wells (MQWs) are widely used in GaAs and InP waveguide devices[2] to enhance optical gain (lasers) or absorption (modulators). Layered structures based on the same epitaxial growth technology have also been used for refractive index control well below the MQW absorption edge. An early application was the use of the inherent MQW birefringence (due to both layering and quantum selection rules) to build integrated optical polarizers, in which only one polarization was guided.[4] More recently, the precise control of MQW properties via epitaxial growth techniques has enabled device designs which improve the optical mode size and minimize polarization dependence.

One such approach involves "diluted MQWs", in which very thin QWs separated by thick barriers are used to create extremely small, yet highly reproducible, refractive index changes. Such small index changes simplify the fabrication of single-mode waveguides with large mode size for improved fiber coupling.[5] It was subsequently recognized that the small index difference in diluted MQW waveguides can provide low birefringence as well.[6] Achieving low birefringence is important in certain wavelength demultiplexers, such as those based on gratings or interferometers, because the polarization-dependence of the multiplexed wavelength is proportional to the guide birefringence.

Other waveguide filters, notably those based on asymmetric directional couplers, require large index changes to achieve narrow passbands. The asymmetric coupler's polarization dependence arises from the differential birefringence of the two coupled waveguides. It has recently been shown that MQWs can be used to alter the birefringence of one coupler guide in order to eliminate the differential birefringence, and thus the polarization dependence.[7] Details of this approach will be described at the conference.

References

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This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.